AG

PCT

WORLD INTELLECTUAL PROPERTY ORGANIZATION
International Bureau

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 6 : H04M 11/06, H04N 7/10, H04L 12/28	A1	(11) International Publication Number: WO 97/44947 (43) International Publication Date: 27 November 1997 (27.11.97)

(21) International Application Number: PCT/US97/07910

(22) International Filing Date: 9 May 1997 (09.05.97)

(30) Priority Data:
08/653,660 21 May 1996 (21.05.96) US

(71) Applicant: INTEGRATED NETWORK CORPORATION [US/US]; 757 Route 202/206, Bridgewater Corporate Park, Bridgewater, NJ 08807 (US).

(72) Inventor: GUPTA, Dev, V.; 10 Shurts Road, Flemington, NJ 08822 (US).

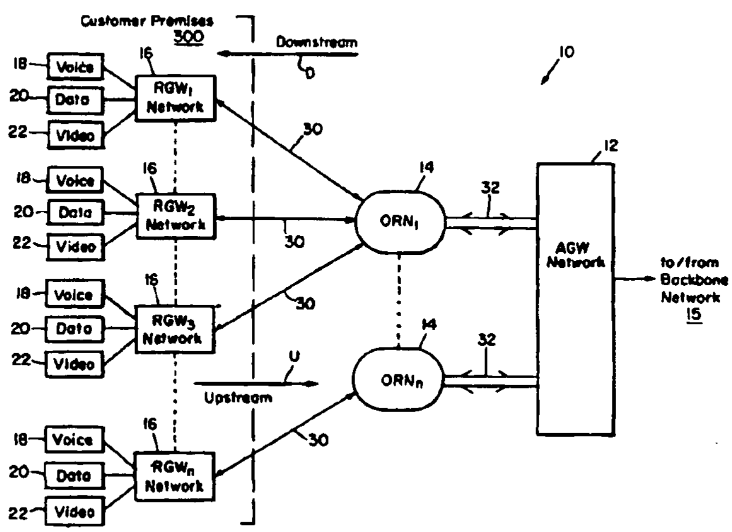
(74) Agents: REYNOLDS, Leo, R. et al.; Hamilton, Brook, Smith & Reynolds, P.C., Two Militia Drive, Lexington, MA 02173 (US).

(81) Designated States: AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GE, GH, HU, IL, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, TJ, TM, TR, TT, UA, UG, UZ, VN, YU, ARIPO patent (GH, KE, LS, MW, SD, SZ, UG), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, NE, SN, TD, TG).

Published

With international search report.
Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.

(54) Title: MULTIMEDIA OVER VOICE COMMUNICATION SYSTEM



(57) Abstract

A communication system is described which enables simultaneous communication of voice, data and video bandwidth signals over a communication network. Signals are transported in a downstream direction from a remote node to a regional gateway system and also transported upstream from the regional gateway system to the remote node. In both cases the signals are transported over the same copper wire media.

FOR THE PURPOSES OF INFORMATION ONLY

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AL	Albania	ES	Spain	LS	Lesotho	SI	Slovenia
AM	Armenia	FI	Finland	LT	Lithuania	SK	Slovakia
AT	Austria	FR	France	LU	Luxembourg	SN	Senegal
AU	Australia	GA	Gabon	LV	Latvia	SZ	Swaziland
AZ	Azerbaijan	GB	United Kingdom	MC	Monaco	TD	Chad
BA	Bosnia and Herzegovina	GE	Georgia	MD	Republic of Moldova	TG	Togo
BB	Barbados	GH	Ghana	MG	Madagascar	TJ	Tajikistan
BE	Belgium	GN	Guinea	MK	The former Yugoslav Republic of Macedonia	TM	Turkmenistan
BF	Burkina Faso	GR	Greece			TR	Turkey
BG	Bulgaria	HU	Hungary	ML	Mali	TT	Trinidad and Tobago
BJ	Benin	IE	Ireland	MN	Mongolia	UA	Ukraine
BR	Brazil	IL	Israel	MR	Mauritania	UG	Uganda
BY	Belarus	IS	Iceland	MW	Malawi	US	United States of America
CA	Canada	IT	Italy	MX	Mexico	UZ	Uzbekistan
CF	Central African Republic	JP	Japan	NE	Niger	VN	Viet Nam
CG	Congo	KE	Kenya	NL	Netherlands	YU	Yugoslavia
CH	Switzerland	KG	Kyrgyzstan	NO	Norway	ZW	Zimbabwe
CI	Côte d'Ivoire	KP	Democratic People's Republic of Korea	NZ	New Zealand		
CM	Cameroon			PL	Poland		
CN	China	KR	Republic of Korea	PT	Portugal		
CU	Cuba	KZ	Kazakstan	RO	Romania		
CZ	Czech Republic	LC	Saint Lucia	RU	Russian Federation		
DE	Germany	LI	Liechtenstein	SD	Sudan		
DK	Denmark	LK	Sri Lanka	SE	Sweden		
EE	Estonia	LR	Liberia	SG	Singapore		

MULTIMEDIA OVER VOICE COMMUNICATION SYSTEM

Background of the Invention

Today's public communication network consists of many separate end-to-end service networks. Private leased line networks are deployed for enterprise networking. The Public Switched Telephone Network is utilized for telephony. Data networking utilizes X.25 public packet networks or emerging frame relay or Switched Multimegabit Data Service (SMDS) networks. Television is provided by a separate satellite/fiber/coaxial cable network.

Currently service subscribers, or end users, have separate connections to their homes for each service to which they subscribe. A phone line connects the handset to the local telephone company. Broadband coax cable is used to connect the VCR and TV to the local cable company's transmitter. Also, a separate phone line may be required to connect to the family PC Internet access, computer subscription services, or a local electronic bulletin board.

Separate lines for separate services were expected in the past because the information carrying capacity limited the connection to one service. Today, end users need a full service network that can accommodate nearly all services. Clearly, an efficient solution is needed to take advantage of the old narrowband and new wideband network options, including copper wire, coax and fiber.

Significant investments have been made and are continuing to be made in separate backbone networks for use with specific applications. In addition, new backbone networks are envisioned for new applications. For example, the Internet handles many of today's information and messaging services; interactive video is

expected to use Asychronous Transfer Mode (ATM) backbones.

These applications will continue to use these backbone networks. However, the key to delivering these services to the home via one connection is a Multimedia Access Network consisting of a layer of distributed access gateways. These gateways would be compatible with a variety of distribution loop technologies (*e.g.*, copper pairs, fiber/coax, or switched digital fiber) and would permit network operators to upgrade their cable infrastructure and topologies over time without needing to replace the gateways themselves. The access network would use a loop format which will become the basis for the standard multimedia transmission to the home.

While providing service adaption and access, the network would also offer routing to the appropriate backbone, switching and broadcasting, and level 1 gateway (*i.e.*, subscriber interaction) functionality.

Multimedia communication requires the simultaneous delivery of time synchronized audio, video and data signals. A Multimedia Access Network has the task of delivering such signals to and from a switching entity and a multiple subscriber premises which it services. The switching entity acts as a gateway to the rest of the world and allows the subscribers access into the (multiple) backbone networks terminating on it. For this reason the switching entity can be called an Access Gateway (AGW). In general, the switching entity may not be geographically centralized. It may consist of a centralized access node connected with one or more remote nodes.

At the customer's premise, a Residential Gateway (RGW) terminates the multimedia signals from the switching entity AGW and regenerates the communication services being consumed.

The AGW must communicate with the RGW over some physical media. This media may be wireless or wireline. Multimedia wireless communication is a topic undergoing much research and is an emerging technology. The most common wireline media currently deployed uses Hybrid Fiber Co-Ax (HFC) drops for broadcast video services and twisted pair copper drops for Plain Old Telephone Signals (POTS) services.

U.S. Patent Application Serial No. 08/269,370, now U.S. Patent No. 5,555,244, issued September 10, 1996, entitled "Scalable Multimedia Networks" (incorporated herein in its entirety by reference), is concerned with many of the problems associated with the suitability of multimedia communication services on an AGW.

HFC drop networks are deployed by CATV operators and have the advantage that they are based on intrinsically broadband physical media. Co-Axial cable is capable of carrying signals out into the hundreds of megahertz (even a gigahertz on modern cable) to the subscriber. However, HFC networks are deployed as shared media where hundreds (even thousands) of subscribers tap onto one run of cable. Such an architecture is highly cost-effective for broadcast services, but creates a difficult multiple access problem when the RGWs at the subscriber try to communicate with the AGW.

Copper drop networks are deployed by telephone operators and have the advantage that they are star connected. Each RGW has its own connection with the AGW. However, copper, as deployed in the telephone plant, is not an effective broadband physical medium and is fundamentally designed to provide physical transport in the 0-4 KHz base band region over 1300 ohms of wire.

Current (second generation) Fiber-To-The-Curb (FTTC) networks are being deployed by the telephone operator to overcome the above mentioned problem with

the copper drops. In such FTTC networks, optical fiber connects an Optical Network Unit (ONU) mounted in outside plant (on poles or in manholes) to the AGW. From th ONU, co-ax and (pre-existing) copper runs are used to provide POTS and broadband services to the subscriber.

The problem with such an FTTC network is that it involves "curb cracking." The subscriber's premises' curbside has to be dug for the co-ax to be installed. This is a labor intensive and expensive operation.

A need exists therefore to provide on short runs, such as <1300 ohms of copper, transport for both POTS and broadband data and video signals. If a sufficient reach could be implemented on existing copper, the "curb-cracking" problem would be resolved, and the telephone operators would be able to provide a complete Multiple Access Network system to subscribers.

Summary of the Invention

In accordance with the invention a multimedia system is provided which has the ability to simultaneously transmit voice (POTS), and data and video bandwidth signals from a remote node (RN) to a local node, such as a regional gateway (RGW) system (Downstream Direction) and to send such signals from the RGW to the RN (Upstream) direction. The RN may, for example, comprise an Optical Remote Node (ORN) mounted in an outside plant (on poles or in manholes) which is connected upstream to an Access Gateway Network (AGW) via a wideband fiber optic communication link. The ORN is described in more detail in copending U.S. Application Serial No. 08/651,825, filed concurrently herewith (Attorney Docket No. INC96-02), which is incorporated herein in its entirety by reference. The AGW, in turn, may be connected to the world via a backbone network as described, for example, in the

aforementioned "Scalable Multimedia Network." On the downstream side, the ORN is connected to a multiplicity of Regional Gateway Networks (RGWs) via existing or added cooper wire. The RGWs may be located, for example, in the basements of apartment buildings. The RGWs simultaneously supply POTS and multimedia signals to and from subscribers in the apartments after separating out the various signals from the channels in which they are transported.

In accordance with the invention, three transport channels are utilized to transport signals over the copper wire media extending between the ORN and RGWs: a POTS, or voice channel, for bi-directional transport of POTS bandwidth signals, an upstream channel for bi-directional transport of upstream bandwidth signals between the RGWs and the ORN, and a downstream channel for bidirectional transport of downstream bandwidth signals between the ORN and the RGWs.

The voice or POTS channel is coupled to the wire media by a coupling circuit comprised of series connected, low pass and longitudinal filters at the RN and a low pass filter at the RGW. The longitudinal filter is preferably a balanced inductor (BALUN).

The upstream bandwidth signals are modulated at the RGW coupled to the wire media and decoupled at the ORN and demodulated. Preferably Quadrature Phase Shift Keying (QPSK) modulation of a suitable carrier frequency signal at the transmitter and demodulation at the receiver is employed. The downstream bandwidth signals from the ORN are likewise coupled to the media and modulated preferably using a quadrature amplitude modulation (QAM) to transport the broadband downstream signals from the ORN to the RGW where they are decoupled from the media and demodulated.

Brief Description of the Drawings

Fig. 1 is a block-diagram drawing of a multimedia communication system of the invention.

Fig. 2 is an illustration of a copper drop network cell.

Fig. 3 is an illustration of how the collection area of a network cell may be extended.

Fig. 4 is a plot of the spectrum allocation for the multimedia system of the invention.

Fig. 5 is a schematic diagram of a coupling circuit used at the ORN portion of the system.

Fig. 6 is a schematic diagram of a coupling circuit used at the RGW portion of the system.

Fig. 7 is a block diagram of the preferred modulator for the upstream channel of the invention.

Fig. 8 is a block diagram of the preferred demodulator for the upstream channel of the invention.

Fig. 9 is a block diagram of the preferred modulator for the downstream channel of the invention.

Fig. 10 is a block diagram of a preferred demodulator for the downstream channel of the invention.

Description of the Preferred Embodiment of the Invention

Referring now to Fig. 1, there is shown an advanced "filter to the curb" (FTTC) multimedia network 10 in accordance with the invention which does not require "curb cracking" since the optical remote nodes 14 (ORN_1 --- ORN_n) are connected to the RGWs 16 (RGW, RGW_2, RGW_3 --- RGW_n) at the customer premises 300 via existing or added copper wire pairs 30. At the upstream side of the ORNs 14 fiber based broadband media 32, such as a Synchronous Optical Network (SONET) based Asynchronous Transfer Mode (ATM) system may be used to provide POTS and Multimedia service to the ORNs from an Access Gateway Network (AGW) 12. The AGW, in turn, provides multimedia access to/from a Backbone Network 15 as

described in the aforesaid "Scalable Multimedia Network" application.

The RGWs 16 separate out the voice, data and video signals on the respective channels of communication and feed the separated signals to the appropriate voice 18, data 20 or video instruments 22 or sets at the customer/subscriber premises 300.

In order for the copper based FTTC network 10 of the invention to be properly implemented, an analysis of the services to be provided and the physical topology required to deliver the services is required. Table I below summarizes the individual services envisioned for the system and the bandwidth requirements for each. As can be seen, many of the services are highly asymmetrical in their bandwidth requirements, requiring much greater downstream bandwidth than upstream bandwidth.

Table I. Services and Associated Bandwidth Requirements

Service	Downstream BW Per Session	Upstream BW Per Session
Broadcast Video	6 Mbps	
Video On Demand	3 Mbps	1 Kbps*
Telephony	64 Kbps	64 Kbps
Video Teleconferencing	384 Kbps	384 Kbps
Data Communications	PEAK > 1 Mbps Average = 10 Kbps	Peak > 0.1 Mbps Average = 10 Kbps

*Assumption on Interactivity

Table II below shows the bandwidth requirement the copper drop will be expected to support for the service mix desired. From this table it is clear that a downstream channel operating at 20+ Mbps and an upstream channel operating at 600+ Kbps would be adequate to support this service mix. These channels must operate over lifeline POTS service to provide the full gamut of desired residential services.

Table II. Bandwidth Requirements on the Copper Drop for a Full Compliment of Residential Services

Service	# of Simultaneous Sessions	Downstream Bandwidth	Upstream Bandwidth
CATV	0-2	0-12 Mbps	
VOD	0-1	0-3 Mbps	1 Kbps
Telephony	0-1	0-64 Kbps	64 Kbps
Video Teleconf.	0-1	0-384 Kbps	384 Kbps
Data Comm.	0-1	0-(Peak > 1 Mbps Average = 1 Kbps)	0-(Peak > 0.1 Mbps Average = 1 Kbps)
TOTAL	0-6	0-16.448 Mbps	0-549 Kbps

Another important requirement is the reach or signal transmission distance over copper wire. Fig. 2 shows a drop network cell at the center of which the ORN 14 is located. It is envisioned that approximately 500 subscriber premises each allocated 0.5 acres (after accounting for overhead) can be reached from a single ORN.

To cover 250 acres of area, the drop network cell needs to have a diagonal "radius" of 2,000 feet. For suburban/rural areas, collection over a greater area can be effected using the double-star topology shown in Fig. 3 where one or more satellite ORNs 14′ can be homed onto the main ORN 14M using pole-to-pole or manhole-to-manhole co-ax cable over which power and broadband connectivity can be extended.

Based upon the analysis in Tables I and II, it may be seen that a Multimedia-Over-Voice (MOV) copper loop needs to have the ability to transport:

I. Life-line POTS signals;

II. 20+ Mbps downstream signals; and

III. 600+ Kbps upstream signals

simultaneously between the ORN 14 and the RGW 16.

Fig. 4 shows a Frequency Division Multiplex (FDM) architecture for such a loop. The POTS channel occupies the 0-4 KHz band, the upstream channel occupies the ≥

50 KHz to ≤ 1.8 MHz band labeled return link (f1 to f2) and the downstream channel occupies the 2 MHz to 8 MHz band labeled QAM link which stands for Quadrature Amplitude Modulated (f3 to f4).

Coupling System and POTS Channel 50A/50B

Turning now to Figs. 5 and 6, the coupling system for combining and separating (orthogonalizing) the POTS bandwidth channel and the upstream and downstream bandwidth channels as appropriate at the ORN (Fig. 5) and at the RGWs (Fig. 6) will now be described.

First the connectivity of the channel signals coupling circuits will be described in general, then the details of the various circuit components will be described. At the ORN 14 the POTS channel signals from the AGW 12 on the ONU 32, are coupled across the input Tip and Ring wires (T&R) of the ORN coupling circuit 50A. The QAM modulated downstream channel signals at 20+ Mbps from the downstream modulator 90 are coupled to amplifier driver 46 of ORN low impedance coupling circuit 44 for coupling to the output Tip and Ring (To/Ro) wires for transmission over media 30 to the RGW 16. The upstream channel signals at 600 Kbps are input on Tip and Ring wires To/Ro and are coupled through transformer T_1, to output or driver amplifier 48 to the upstream demodulator 60B.

Conversely, the RGW 16 coupling circuit 50B (Fig. 6) the POTS channel signals from the ORN 14 are input to the Tip and Ring input wires and passed directly through Filter LPF1′ to the output Tip and Ring leads (To/Ro) to the telephone unit 18 at the subscriber premises. The downstream channel signals from the downstream transmitter modulator 90 at 20+ Mbps are also coupled across input T&R leads and passed to the input coil 42′ of transformer T1′ to amplifier 48′ where they

are coupled to downstream demodulator - Fig. 10, at the RGW 16.

The upstream channel signals from the subscribers consist mainly of data and/or Video On Demand or teleconferencing signals. These signals are coupled to the input terminal 61 of a Dual Rail Splitter circuit 64 of Upstream Modulator 60A (Fig. 7). The modulated output upstream channel signals are coupled to input amplifier 46' of low impedance circuit 44' of the coupling circuit 50B at the RGW 16 (Fig. 6); where they are coupled via transformer T1' onto the output Tip and Ring Leads T_0 and R_0 onto the copper wire media 30 to the ORN 14 for demodulation at the upstream demodulator 60B (Fig. 8).

The POTS channel signals must not interfere with nor be interfered by the other channels. The band 0-4 KHz must be transparently provided to the POTS system. In its own turn, the POTS system, unless properly conditioned, consists of a large amount of interference outside the 0-4 KHz band which would corrupt the other channels. For example, Dial pulses in the POTS system cause 48V transitions that are abrupt and have an abundance of high frequency content. The sudden engagement of a ringing signal on the POTS channel and its subsequent dis-engagement can cause up to 200V transients that can be very disruptive to the other channels. Furthermore, the ringing signal is applied by grounding the Tip line T while applying the ringing signal to the Ring Line R. This unbalanced signal has high common mode voltages present. Such "longitudinal" signals can be converted to interfering "metallic" (differential) signals by the longitudinal unbalance (poor common mode rejection ratios) of the receiving front ends of the other channel(s).

Passive filtering in the form of a Low Pass Filter LPF1 is used at coupling circuit 50A (Fig. 5) at the ORN

14 for a Low Pass Filter (LPF) function to preserve the life-line nature of this service. A longitudinal filter LF1 is used only at the ORN coupling circuit 50A. LF1 produces a high impedance in the longitudinal path while being essentially transparent in the metallic path. The longitudinal filter LF1 is a balanced inductor (BALUN) in the form of series connected 2 mH inductors L5 and L6 on the Tip (T) and Ring (R) lines respectively. The BALUN is normally bifilar wound as indicated by the polarity dots. The millihenray (mH) inductors L1-L4 at the ORN L1'-L4' at the RGW are provided to present a high impedance in the data band channels and to prevent the POTS low pass filter LPF1 from attenuating the high frequency signals. Note that the longitudinal filter LF1 (described above) is not required at the RGW end 16 (Fig. 6) because the telephone is a balanced ("floating") instrument and produces no longitudinal signals.

Low pass filters LPF1 at the ORN end coupling circuit 50A and LPF1' at the RGW end coupling circuit 50B, respectively, are based on a fourth order 0.25 db ripple Tchebyschef response, scaled to an impedance of 900 Ω and a cut-off frequency of 50 KHz. Filtering at 600 Ω can be achieved by impedance scaling the filtering. A "click" filter CF1 is included across the Tip and Ring lines and is only visible to ringing signals. Low impedance coupling circuits 44 and 44' have low impedance (compared to 900 Ω) and do not seriously degrade the response.

In the upstream and downstream frequency band channels the copper wire 30 has a characteristic impedance in the 100 Ω neighborhood unlike the 600 Ω/900 Ω impedance level for the voice channel. The low impedance coupling circuits 44 and 44' can therefore comprise 1:1 pulse transformers T1 and T1' with a capability to pass the 50 KHz through 10 MHz combined

bandwidth of the upstream and downstream data and video bandwidth signals at a 100 Ω source/100 Ω load impedance level. This can be readily achieved using <0.25 mH coils 40, 40′ on a high frequency ferrite or a powdered iron torridal core 42, 42′ (carbonyl C or better). The windings present minimal impedance relative to the impedance of the 0.018 μF capacitor C1, C1′ in series with T1, T1′ at ≤4 KHz. Therefore, the coupling circuits 44 and 44′ look like they are not present to the POTS band. The 0.018 μF coupling capacitor C1 has a low impedance across the upstream and downstream bands and therefore does not excessively attenuate coupling.

The 20 Hz POTS ringing signals and 48V DC POTS transients that may pass through the POTS Low Pass Filters LPF1 produce most of the voltage over the 0.018 μF coupling capacitor C1 and do not create large voltages across T1. This prevents saturation from occurring at the coupling amplifiers 46, 48.

The "click" filters CF1, CF2, respectively in series with respective 0.47 uF capacitors C5, C5′ across the tip (T) and ring (R) terminals suppresses ringing transients.

The Upstream Channel

Figs. 7 and 8 illustrate a preferred embodiment of the respective digital modulators and demodulators of the upstream channel system of the invention.

The upstream modulator at the RGW maps the digital sequence signals from the subscriber onto a carrier frequency signal having a waveform appropriate for transmission over the copper pair media. In turn, the demodulator at the ORN processes the media corrupted received waveforms to reproduce or recover the original digital sequence. A simplified version of the well-known modulation and demodulation process follows. For more details reference is had to the text *Digital*

Communications, 2d Edition, by John G. Proakis (McGraw-Hill) © 1989, 1983, which is incorporated herein in its entirety by reference.

The spectrum of the 600 Kbps upstream channel, which may contain up to 1 Kbps VOD signals, 64 Kbps telephony signals and 394 Kbps video teleconferencing signals, is sandwiched between the low frequency narrow band spectrum of the POTS channel and the high frequency wide bandwidth downstream channel. The available bandwidth ranges from about 50 KHz to about 1.8 MHz which is a band of about 1.75 MHz. If only video services are required, then the only purpose of the upstream channel is to provide service control from the subscriber to the network via the ORN's 14. Even a 64 Kbps frequency would be adequate for this response with enough left over to provide low bandwidth data communication services over the copper wire medium 30. For such an upstream transmission, a well-known angle based modulation system, such as Frequency Shift Keying (FSK) modulation, suffices and is very cost effective in spite of its low spectral efficiency. To achieve a high bit rate, a well-known Quadrature Phase-Shift Keying (QPSK) based system is preferred. To provide a bit rate of 2.048 Mbps (which is >600 Kbps), a baud rate of 1.024 MHz is used. With a 50% excess bandwidth raised cosine pulse spectrum (see Proakis, *supra*, p. 536) as the basic pulse shape being modulated on each of the I and Q axis, the passband signal extends from 256 KHz to 1.792 MHz, which fits nicely into the desired spectral window and intersymbol interference is avoided.

A modulator circuit 60A (Fig. 7) is provided at the RGW 16 which accepts the input data in standard alternate mark inversion (AMI) bipolar format from the subscriber at 2.048 Mbps. The input signal is split into two 1,024 Mbps bit streams labeled ST1 and ST2, using well-known Dual Rail Splitter circuit 64.

Sampling system clock 72 is used by circuit 64 to sample the input stream at one-half the input data rate to produce the two separate streams ST1 and ST2 of respective positive and negative going pulses. The baseband bit streams are then Pulse Amplitude Modulated onto a carrier frequency signal using raised cosine 50% Excess Bandwidth sinusoidal PAM encoders 62 and 62', respectively, for each data stream. Circuit 67 divides the 2.048 Mbps clock by two and multipliers 66 and 66' create the 90° phase shifted outputs ST3, ST4 (quadrature rails). After raised cosine 50% Excess Bandwidth pulse amplitude modulation of the two bit streams, the two modulated bit streams are re-combined in summing amplifier 68, and passed through (0.256 MHz to 1.792 MH) Low Pass Filter 70. Filter 70 rejects all harmonic content present in the modulating clocks. The output of filter 70 is coupled to amplifier 46' of coupling circuit 50B of Fig. 6 for transmittal over the copper pair 30 to the ORN14 upstream.

At the ORN14 (referring to Fig. 8), the modulated upstream channel signals from coupling circuit 50A at the ORN14 are received at receive filter 74 of demodulator 60B. Filter 74 rejects all signals other than the 2.048 Mpbs signals occupying the 50 KHz to 1.8 MHz upstream channel.

Carrier recovery circuit 76 recovers the carrier signal used in the QAM modulation circuit of Fig. 7 to produce sine and cosine quadrature clock/pulses. Multiplier circuits 78 and 78' recover the transmitted modulated rails which are passed through Low Pass Filters 81 and 81' to Equalizer 80.

The split rail demodulated bit stream is equalized to compensate for transmission losses in equalizer 80 and detected by decision device 82, which includes a slicer circuit (not shown) and a comparator (not shown) which determines when the incoming signal exceeds a

predetermined threshold and is therefore a valid data signal. The two demodulated bit streams ST1 and ST2 are combined in (well known) Dual Rail combiner 84 by alternating bits from the two rails to re-create the 2.048 Mpbs upstream data from the RGW modulator 60A. The demodulated signals are coupled to AGW12 via ONU media 32. Carrier recovery circuit 76 is also used to regenerate the 2,048 Mbps clock signal from the RGW16 to synchronize the equalizer and decision device circuits 80 and 82, respectively.

The Downstream Channel

The Downstream Channel modulator 90 and demodulator 900 are depicted in general in Fig. 9 and Fig. 10, respectively. In accordance with Table II a full complement downstream channel requires up to 16.448 Mbps. The downstream channel uses a frequency band starting from 2.0 MHz. Either 16 Quadrature Amplitude Modulation (QAM) or 64 QAM technology (as defined in Proakis, *supra*, pp. 227-285) may be used to transport the downstream channel over the copper wire from the ORN 14 to the RGW 16. A 16 QAM technology can be used to achieve a 20 Mbps bit rate in which case, the baud rate must be 5 Mbaud. Also, 20% excess bandwidth raised cosine pulses are preferably the basic pulse shapes used on each of the I, Q axis, in which case the passband signal will occupy the 2 MHz to 8 MHz band. If the same band is used with 64 QAM, a bit rate of 30 Mbps can be achieved.

Normally, the downstream channel will suffer from reflections due to bridge taps (unterminated wire attached to the copper loop) in the form of incorrectly made splices. Thus, even though linear equalization will resolve dispersion due to straight wire, a Decision Feedback Equalizer (DFE) circuit 120 is used in the Modulator 90 to eliminate echoes due to reflections. A

16 Tap Feed Forward Equalizer 102 (8 feedforward taps and 8 feedback taps) in the DFE 120 provides adequate performance for up to 2,000 feet of 24 gauge copper wire media.

Since energy can be collected from impulse noise sources (chattering relays, light dimmers, electric motors, etc.), therefore interleaving along with Forward Error Correction (FEC) is employed to eliminate degraded performance due to impulse noise. FEC also enhances the error performance due to far end cross talk between MOV signals in the wires running adjacently in the binder group.

When High Bit Rate Downstream Bandwidth Signals from the AGW12 and received at the ORN14 for transmittal to an RGW they are first coupled to input port 96 of downstream channel 90 and split into I and Q channels by raised cosine quadrature amplitude modulation carrier by oscillator 95 at respective cosine modulator 94, and sine modulator 94'. The digitally modulated I and Q downstream signals are coupled to DFE circuit 120 comprising feed forward equalizer 102 coupled to respective I and Q rail summing amplifiers 104, 104' and threshold detectors 106, 106'; the outputs of which are combined in combiner 110 and passed to low impedance amplifier 46 at the ORN coupling circuit 50A for transmission over the copper wire media 30 to the RGW. Acquisition and Tracking Loops circuit 92 provides clock synchronization pulses.

The downstream demodulator 900 is functionally equivalent to the upstream demodulator 60B. The QAM modulated downstream carrier signal from the RGW coupling circuit 50B at the low impedance amplifier 48' is coupled to receive filter 740 and demodulated into two bit streams by mixing with the carrier signal in mixers 780 and 780'. The carrier signal is recovered in circuit 760. The demodulated signals are passed through

low-pass-filters 781, 781', equalized in equalizer 800 and detected in decision device 820. The detected signals are combined in combiner 840 and coupled to the subscriber at the customer premises 300.

A multimedia over voice communication system has been described above using 16 QAM a 20 Mbps (18 Mbps after FEC) signal along with a 2.048 Mbps upstream signal which can be transferred over 2,000 feet of 24 gauge wire in the presence of impulse noise and 1% FEXT while maintaining a Bit Error Rate (BER) of $<10^{-8}$. This capability exists over POTS. The POTS channel simultaneously meets all requirements imposed on it for local telephony.

Having thus described a particular embodiment of the invention, various alterations, modifications and improvements will readily occur to those skilled in the art. Such alterations, modifications and improvements as are made obvious by this disclosure are intended to be part of this description though not expressly stated herein, and are intended to be within the spirit and scope of the invention. Accordingly, the foregoing description is by way of example only, and not limiting. The invention is limited only as defined in the following claims and equivalents thereto.

CLAIMS

We claim:

1. A communication system for simultaneous communication of voice, data and video bandwidth signals in a downstream direction from a remote node to a local node and upstream from the local node to the remote node over copper wire media comprising:
   a) a first coupling circuit at the remote node for coupling respective voice, data and video bandwidth signals to a respective first voice, downstream and upstream channel of the media;
   b) a second coupling circuit at the local node for coupling respective voice, data and video bandwidth signals to said second respective voice channel and said downstream and upstream channels of the media.

2. The system of Claim 1 wherein the voice channel has a bandwidth extending up to 4 KHz, the upstream channel bandwidth extends from above 4 KHz to less than 2.0 MHz and the downstream channel from 2 MHz to at least 8 MHz.

3. The system of Claim 1 wherein the first coupling circuit is operatively associated with the remote node and comprises a first passive low pass filter in series with a passive longitudinal filter and the second coupling circuit is operatively associated with the local node and comprises a second passive low pass filter.

4. The system of Claim 3 wherein the longitudinal filter is comprised of a balanced inductor for providing a high impedance along a longitudinal

channel path while being essentially transparent along a metallic channel path.

5. The system of Claim 1 wherein the upstream channel is comprised of a modulator which splits the data bandwidth signals from the local node into two bit streams each of which is separately pulse amplitude modulated onto a carrier frequency signal by a raised cosine function on each of two orthogonal axes and combined and passed through a low pass filter in an upstream direction toward the remote node and a demodulator which receives the modulated and combined signals from the remote node and passes them through a receive filter having a pass band to a carrier recovery circuit where the carrier frequency signal is recovered and mixed with the modulated and combined signal to provide a demodulated data bandwidth signal in each of two alternate data streams which are then equalized and combined to form a data bandwidth signal for transmission over the media toward the local node.

6. A communication system for simultaneous communication of voice, data and video bandwidth signals in a downstream direction from a remote node to a local node and upstream from the local node to the remote node over copper wire media comprising:

a) a first coupling circuit at the remote node for coupling a first voice channel signal and a modulated downstream channel signal to the media and for receiving a second voice channel signal and modulated upstream channel signal from the media;

b) a second coupling circuit at the local node for receiving the first voice channel signal

and modulated downstream channel signal from the media and for coupling an upstream channel signal to the media.

7. The system of Claim 6 wherein the first and second voice channel signals have a bandwidth extending from 0 to 4 KHz, the upstream channel signal has a bandwidth which extends from 50 KHz to 1.8 MHz and the downstream channel signal has a bandwidth which extends from 2 MHz to at least 8 MHz.

8. The system of Claim 6 wherein the first coupling circuit is operatively associated with the remote node and comprises a first passive low pass filter in series with a passive longitudinal filter and the second coupling circuit is operatively associated with the local node and comprises a second passive low pass filter.

9. The system of Claim 8 wherein the longitudinal filter is comprised of a balanced inductor for providing a high impedance along a longitudinal path while being essentially transparent along a metallic path.

10. The system of Claim 6 including an upstream modulator which receives the upstream channel signal from a subscriber and splits the signal into two bit streams each of which is separately pulse amplitude modulated onto an upstream carrier frequency signal by a raised cosine function on each of two orthogonal axes and combined and passed to the second coupling circuit for transport in an upstream direction toward the first coupling circuit at the remote node and an upstream demodulator which receives the modulated and

combined signals from the first coupling circuit and passes them through a pass band receive filter, a carrier recovery circuit where the upstream carrier frequency signal is recovered and mixed with the modulated and combined signal to provide a demodulated upstream channel signal in each of two alternate data streams which are then equalized and combined to reconstruct the upstream channel signal for transmission to a backbone network.

11. A remote node coupling system for coupling communication signals from a backbone network to and from a local node over a copper wire media, the system comprising tip and ring input terminals coupled to a POTS communication channel, a remote node low impedance circuit having a downstream channel input signal coupled over a low impedance path to a tip and ring output terminal of the copper wire media and an upstream output signal coupled to a demodulator for demodulation and coupling to said backbone network.

12. The local node coupling system of Claim 7 including a click filter across the tip and ring input terminals.

13. The local node coupling system of Claim 7 wherein the local node low impedance circuit is comprised of an input and output amplifier coupled to the secondary windings of a transformer and where the primary windings of the transformer are AC coupled across the tip and ring output terminals.

14. The local node coupling system of Claim 10 further including a click filter across the tip and ring input leads and a low pass filter in a conductive

path between the input tip and ring leads and the output tip and ring leads.

15. The system of Claim 6 including a downstream digital modulator which receives the downstream channel signal and pulse amplitude modulates it onto a downstream carrier frequency signal for coupling to the first coupling circuit, and a downstream digital demodulator coupled to the second coupling circuit for receiving the modulated downstream channel signal in which the downstream carrier frequency signal is recovered and mixed with the modulated downstream channel signal to produce a demodulated downstream channel signal for transmission to a subscriber.

16. A local node coupling system for coupling communication signals from a subscriber to and from a copper wire media, the system comprising tip and ring input terminals coupled to a subscriber's telephone, a local node low impedance circuit having an upstream channel input signal and a downstream channel output signal, and wherein the output signal is coupled to a digital demodulator for demodulation and coupling to a subscriber's video and data terminals, and the input signal is coupled over a low impedance path to a tip and ring output terminal of the copper wire media.

17. A downstream channel for bidirectionally transporting downstream bandwidth signals between a local node and a remote node over copper wire media comprising:

a) a downstream modulator operatively associated with the remote node for pulse amplitude

modulating the downstream bandwidth signals onto a downstream carrier frequency signal;

b) a remote node coupling circuit for coupling the downstream carrier frequency signal onto the copper wire media for transport to the local node coupling circuit;

c) A local node coupling circuit for coupling the downstream carrier frequency signal from the copper wire media to a demodulator circuit for recovery of the downstream bandwidth signals; and

an upstream channel for bidirectionally transporting upstream bandwidth signals between said local node and said remote node over said copper wire media comprising:

d) an upstream modulator operatively associated with the local node for pulse amplitude modulating the upstream bandwidth signals onto an upstream carrier frequency signal;

e) said local node coupling circuit also coupling the upstream carrier frequency signal onto the copper wire media for transport to the remote node coupling circuit;

f) said remote node coupling circuit also coupling the upstream carrier frequency signal from the copper wire media to a demodulator circuit for recovery of the upstream bandwidth signals; and

a voice channel for bidirectionally transporting voice bandwidth signals between said local node and said remote node over said copper wire media comprising:

g) input tip and ring terminals connecting a telephone to said local node coupling circuit for coupling voice bandwidth signals from the telephone to said copper wire media and tip

and ring output terminals for coupling the voice bandwidth signals from the copper wire media to the remote node.

18. The system of Claim 17 wherein the bandwidth of the downstream signals is greater than 2 MHz; and the bandwidth of the upstream signal is greater than 4 KHz and less than 2 MHz.

19. The system of Claim 17 wherein the downstream and upstream modulators are quadrature amplitude modulators.

20. The system of Claim 17 wherein the downstream signals include broadcast video signals occupying 12 Mbps of bandwidth, video on demand signals occupying 3 Mbps of bandwidth and telephony signals occupying 64 Kpbs of bandwidth, and wherein the upstream signals include said video demand signals and telephony signals.

21. A method of communication for simultaneous communication of voice, data and video bandwidth signals in a downstream direction from a remote node to a local node and upstream from the local node to the remote node over copper wire media comprising the steps of:

a) coupling respective voice, data and video bandwidth signals to a respective first voice channel, downstream channel and upstream channel of the media;

b) coupling respective voice, data and video bandwidth signals to a second respective voice channel and downstream channel and upstream channel of the media.

22. The method of Claim 21 wherein the voice channel has a bandwidth extending up to 4 KHz, the upstream channel bandwidth extends from above 4 KHz to less than 2.0 MHz and the downstream channel from 2 MHz to at least 8 MHz.

23. The method of Claim 21 including the steps of splitting the data bandwidth signals into two bit streams each of which is separately pulse amplitude modulated onto a carrier frequency signal by a raised cosine function on each of two orthogonal axes and combined and passed through a low pass filter in an upstream direction toward the remote node and a demodulator which receives the modulated and combined signals from the remote node and passes them through a receive filter having a pass band to a carrier recovery circuit where the carrier frequency signal is recovered and mixed with the modulated and combined signal to provide a demodulated data bandwidth signal in each of two alternate data streams which are then equalized and combined to form a data bandwidth signal for transmission over the media toward the local node.

24. A method for simultaneous communication of voice, data and video bandwidth signals in a downstream direction from a remote node to a local node and upstream from the local node to the remote node over copper wire media comprising the steps of:

a) coupling a first voice channel signal and a modulated downstream channel signal to the media;

b) receiving a second voice channel signal and modulated upstream channel signal from the media;

c) receiving the first voice channel signal and modulated downstream channel signal from the media; and

d) coupling an upstream channel signal to the media.

25. The method of Claim 24 wherein the first and second voice channel signals have a bandwidth extending from 0 to 4 KHz, the upstream channel signal has a bandwidth which extends from 50 KHz to 1.8 MHz and the downstream channel signal has a bandwidth which extends from 2 MHz to at least 8 MHz.

26. A method of bidirectionally transporting downstream bandwidth signals between a local node and a remote node over copper wire media comprising the steps of:

a) modulating the downstream bandwidth signals onto a downstream carrier frequency signal;

b) coupling the downstream carrier frequency signal onto the copper wire media for transport to a local node coupling circuit;

c) coupling the downstream carrier frequency signal from the copper wire media to a demodulator circuit for recovery of the downstream bandwidth signals; and

bidirectionally transporting upstream bandwidth signals between said local node and said remote node over said copper wire media comprising the steps of:

d) modulating the upstream bandwidth signals onto an upstream carrier frequency signal;

e) coupling the upstream carrier frequency signal onto the copper wire media for transport to the remote node coupling circuit;

f) coupling the upstream carrier frequency signal from the copper wire media to a demodulator circuit for recovery of the upstream bandwidth signals; and

bidirectionally transporting voice bandwidth signals between said local node and said remote node over said copper wire media comprising the steps of:

g) coupling voice bandwidth signals from a telephone to said copper wire media and coupling the voice bandwidth signals from the copper wire media to the remote node.

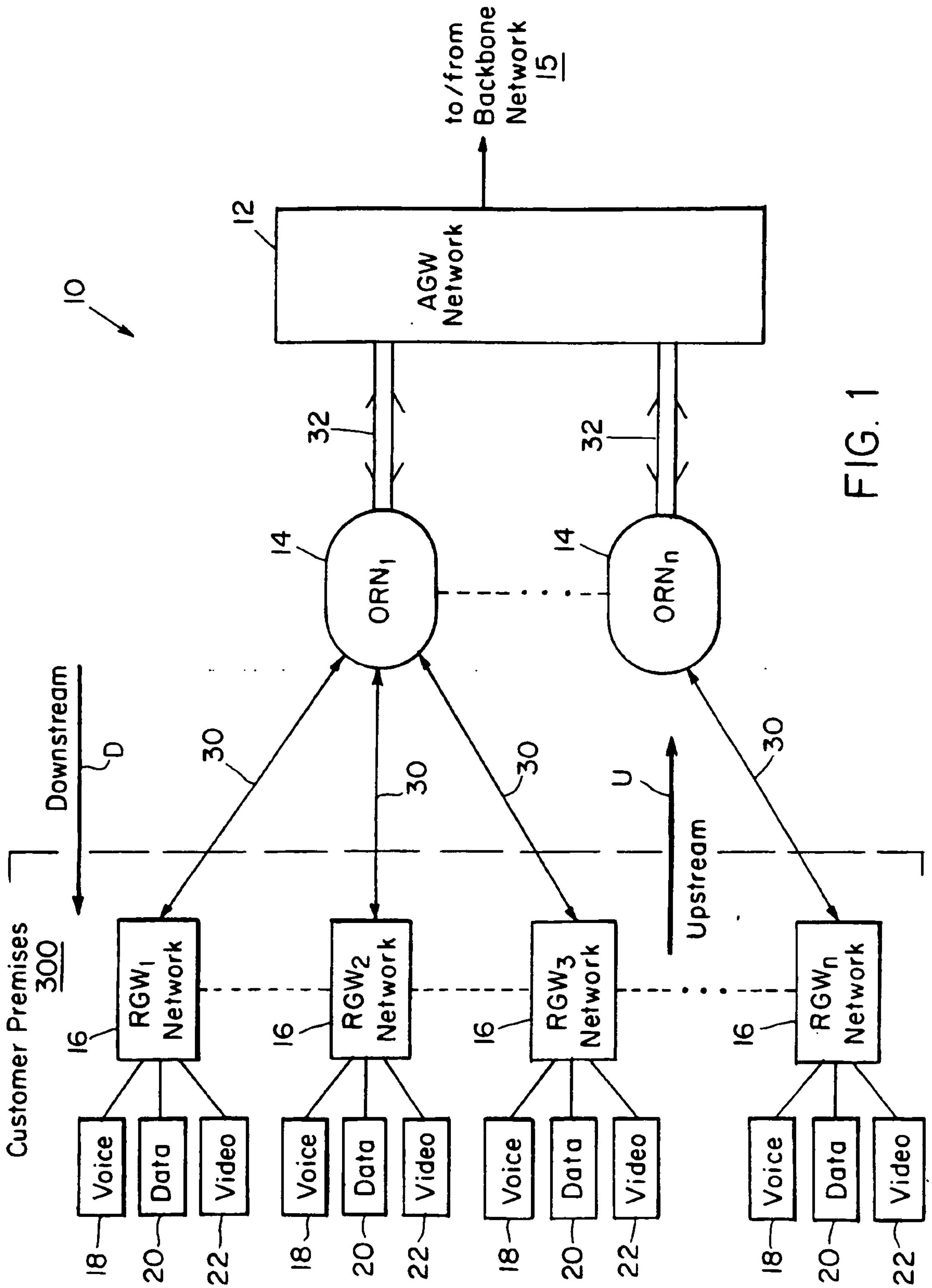

to/from Backbone Network 15
12
AGW Network
10
32
32
14
ORN$_1$
14
ORN$_n$
Downstream
D
30
30
30
30
U
Upstream
Customer Premises 300
16
RGW$_1$ Network
16
RGW$_2$ Network
16
RGW$_3$ Network
16
RGW$_n$ Network
Voice
Data
Video
18
20
22

FIG. 1

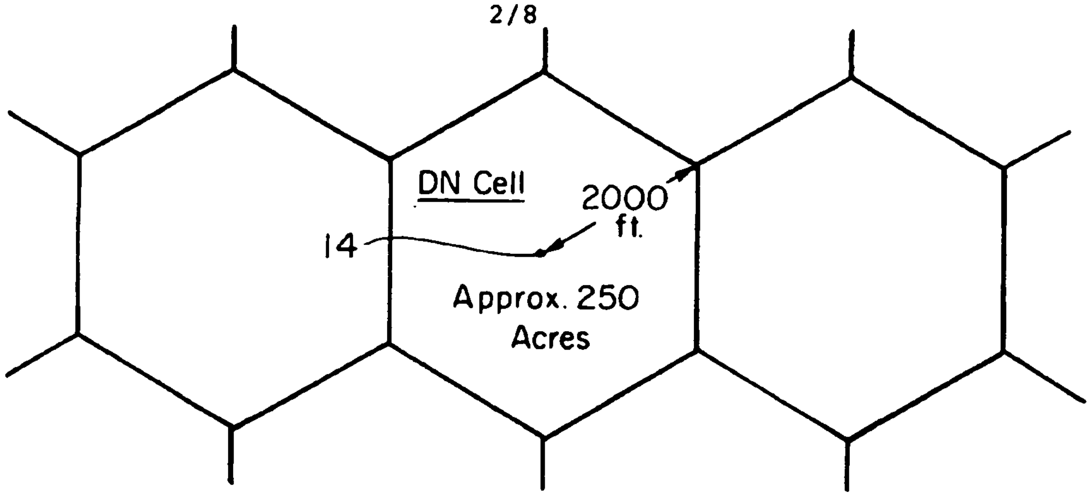


FIG. 2

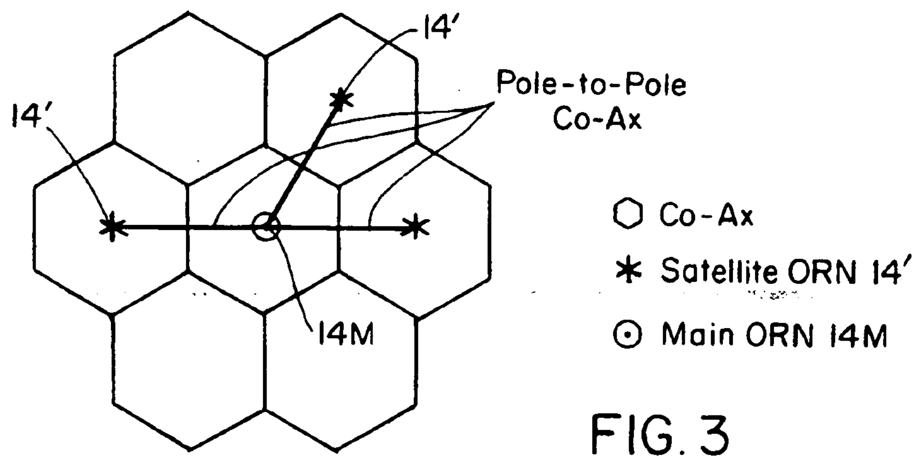


FIG. 3

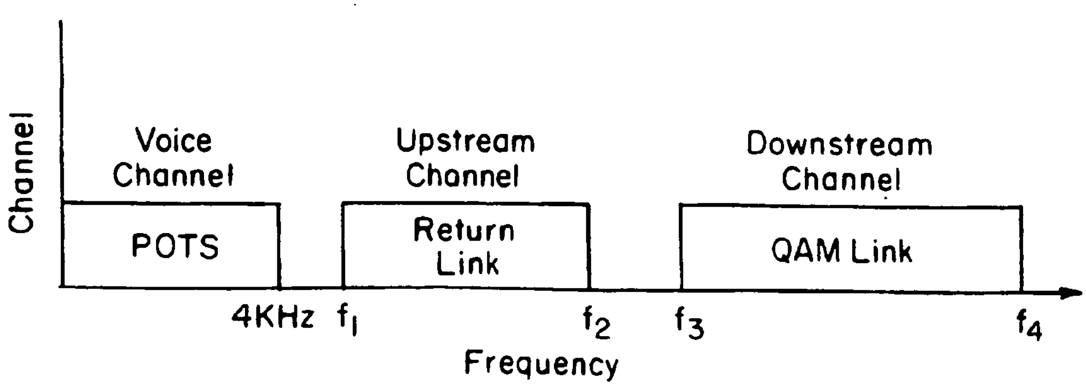


FIG. 4

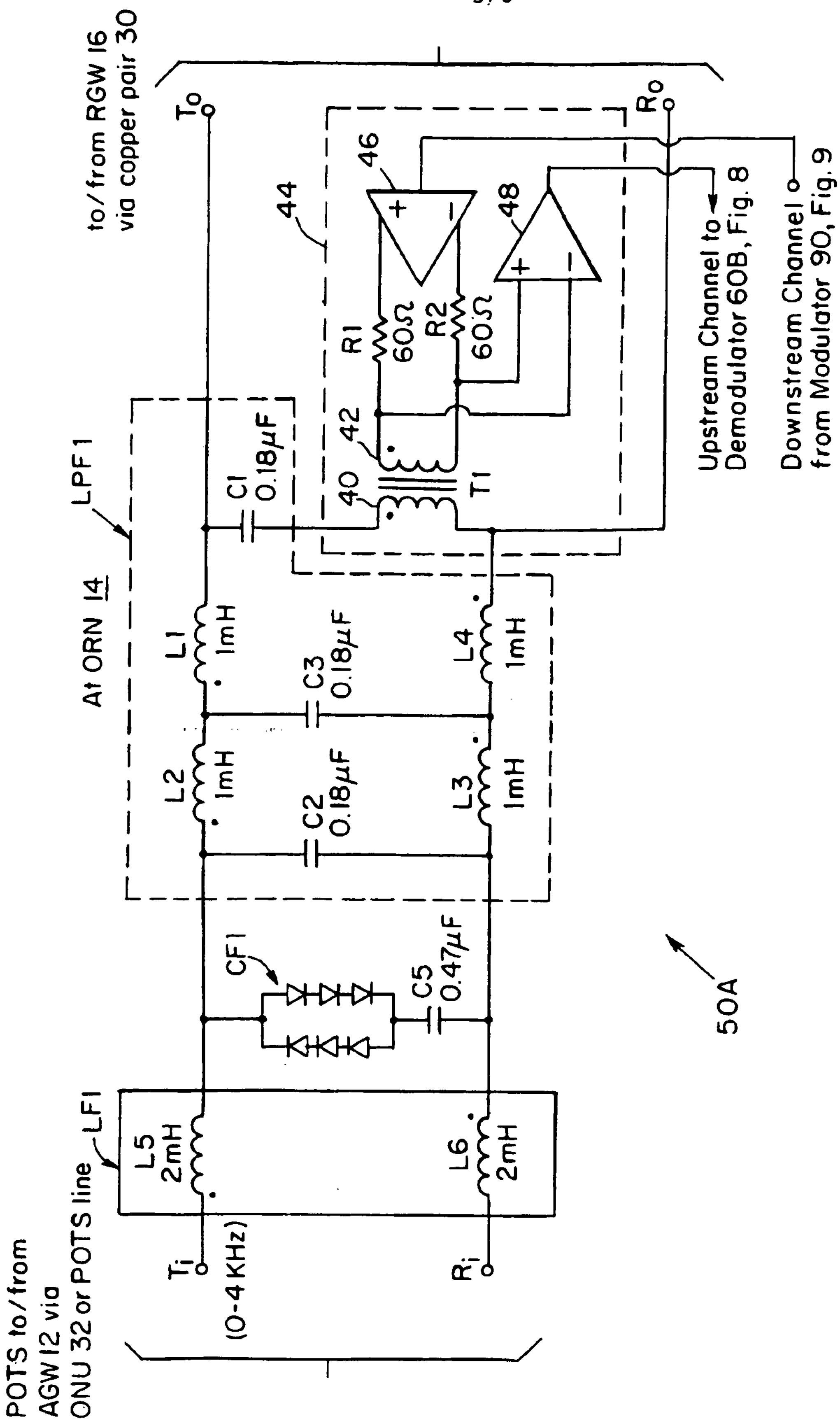

to/from RGW 16
via copper pair 30
To
Ro
44
46
48
Upstream Channel to
Demodulator 60B, Fig. 8
Downstream Channel
from Modulator 90, Fig. 9
R1
60Ω
R2
60Ω
42
40
T1
C1
0.18µF
LPF1
At ORN 14
L1
1mH
L4
1mH
C3
0.18µF
L2
1mH
L3
1mH
C2
0.18µF
CF1
C5
0.47µF
50A
LF1
L5
2mH
L6
2mH
Ti
Ri
(0-4 KHz)
POTS to/from
AGW 12 via
ONU 32 or POTS line

FIG. 5

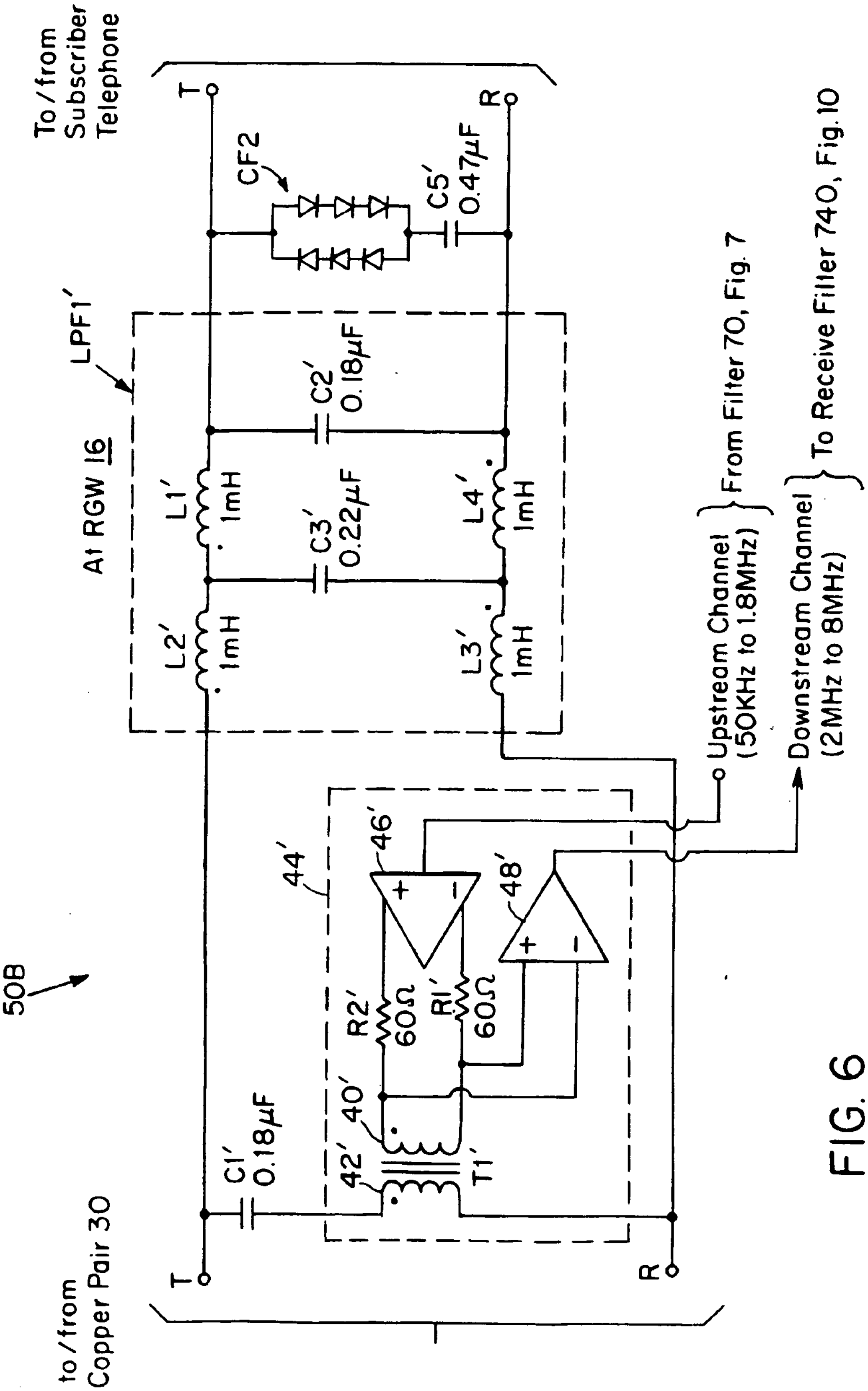

To/from Subscriber Telephone
T
R
CF2
C5'
0.47μF
LPF1'
At RGW 16
C2'
0.18μF
L1'
1mH
C3'
0.22μF
L4'
1mH
L2'
1mH
L3'
1mH
Upstream Channel (50KHz to 1.8MHz)
From Filter 70, Fig. 7
Downstream Channel (2MHz to 8MHz)
To Receive Filter 740, Fig. 10
44'
46'
48'
50B
R2'
60Ω
R1'
60Ω
40'
42'
T1'
C1'
0.18μF
to/from Copper Pair 30
T
R

FIG. 6

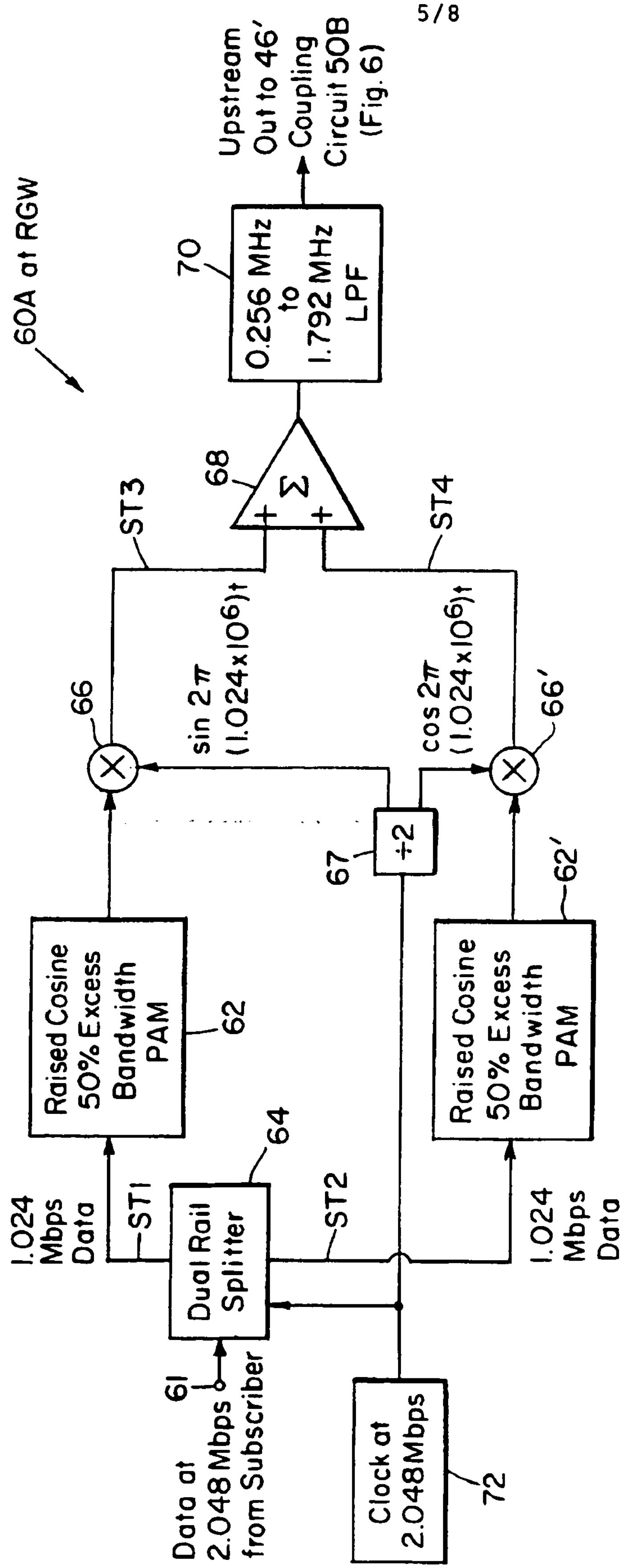


FIG. 7
UPSTREAM MODULATOR at RGW

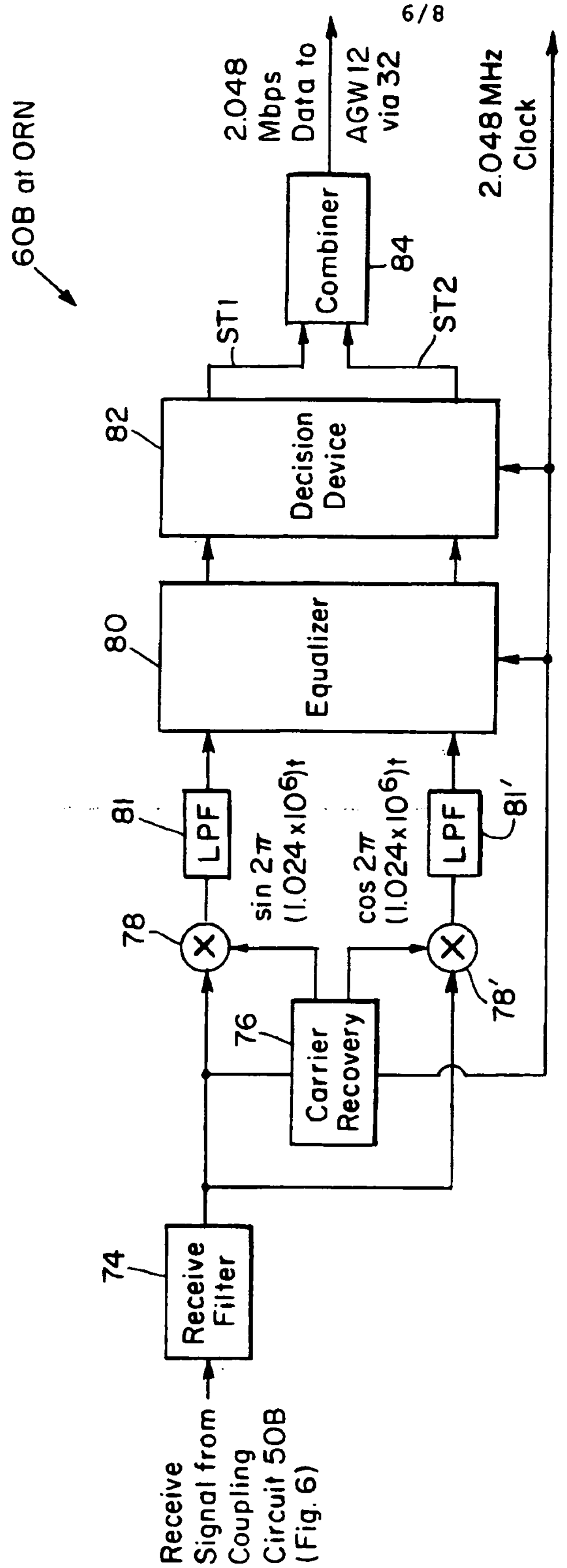


FIG. 8

UPSTREAM RECEIVER/DEMODULATOR at ORN

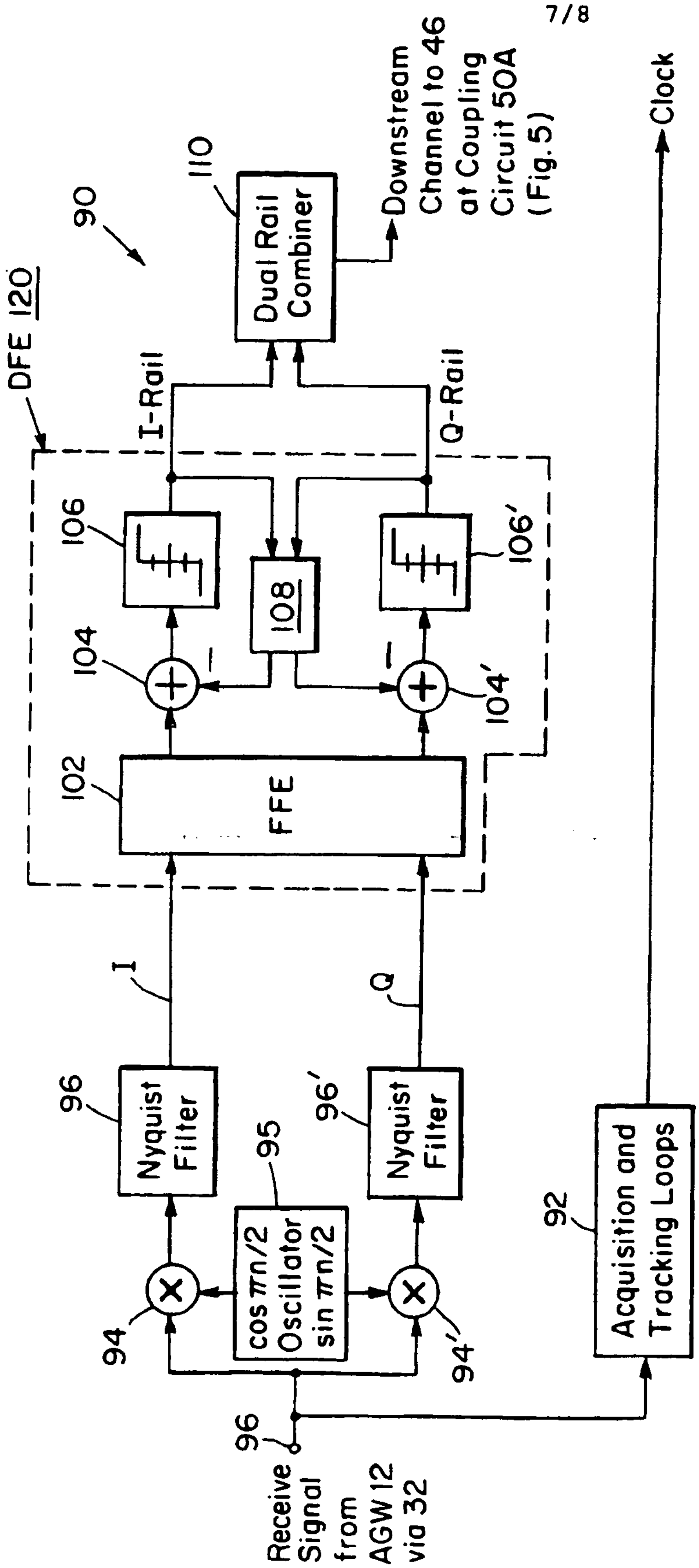


FIG. 9
DOWNSTREAM TRANSMITTER/MODULATOR at ORN 14

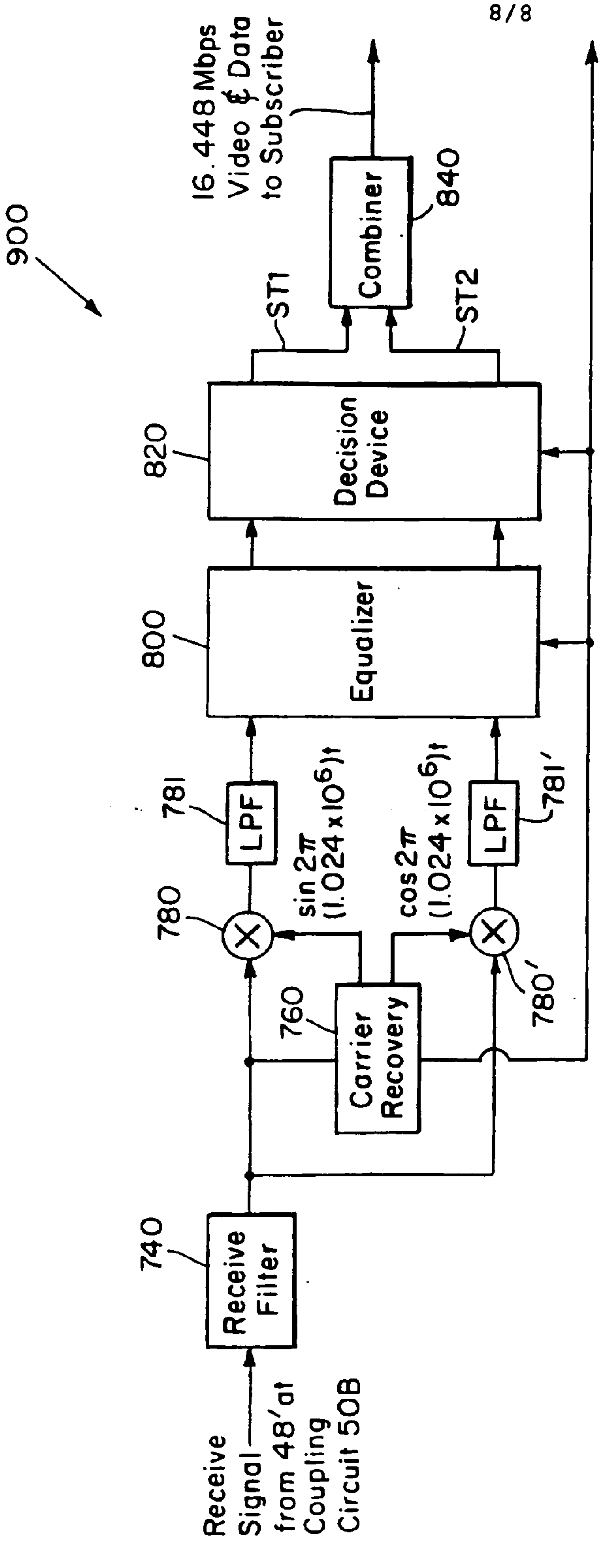


FIG. 10

DOWNSTREAM DEMODULATOR

INTERNATIONAL SEARCH REPORT

Inter. Application No
PCT/US 97/07910

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 H04M11/06 H04N7/10 H04L12/28

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 H04M H04N H04L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	INTERNATIONAL SYMPOSIUM ON SUBSCRIBER LOOPS & SERVICES ISSL 96, 4 - 9 February 1996, MELBOURNE AU, pages 56-61, XP002040951 JOHANSSON A: "VDSL-BROADBAND OVER COPPER" see the whole document ---	1,2,5-7, 10,11, 15-26
X	ELECTRONIC DESIGN, vol. 43, no. 20, - October 1995 CLEVELAND US, page 51/52, 54, 59/60 XP000550493 GOLDBERG L: "BRAINS AND BANDWIDTH: FIBER SERVICE AT COPPER PRICES" see the whole document ---	1,5,6, 10,11, 15-17, 19,21, 23,24,26

-/--

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

1

Date of the actual completion of the international search	Date of mailing of the international search report
17 September 1997	01.10.97
Name and mailing address of the ISA European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+ 31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+ 31-70) 340-3016	Authorized officer Mikkelsen, C

Form PCT/ISA/210 (second sheet) (July 1992)

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/US 97/07910

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 8806821 A	07-09-88	US 4785448 A	15-11-88
		AU 1485688 A	26-09-88
		CA 1285668 A	02-07-91

US 096726600BP1

Creation date: 09-03-2004
Indexing Officer: CDAVIS8 - CHLOE DAVIS
Team: OIPEBackFileIndexing
Dossier: 09672660

Legal Date: 12-14-2001

No.	Doccode	Number of pages
1	IMIS	1

Total number of pages: 1

Remarks:

Order of re-scan issued on ....